



Phytoremediation of TCE in a Shallow Alluvial Aquifer...A Field Demonstration

Sandra M. Eberts, USGS; Gregory J. Harvey, U.S. Air Force





Objective

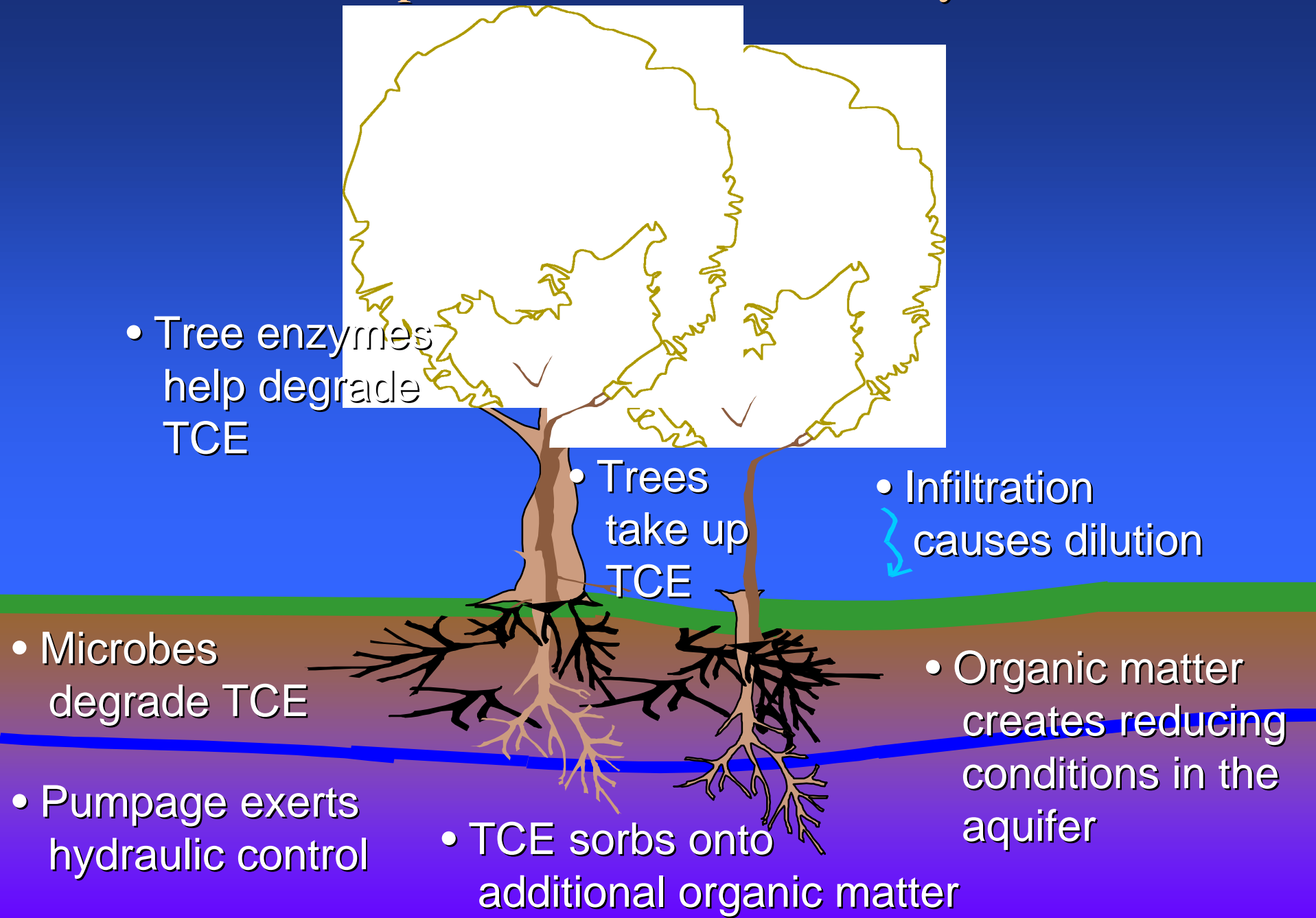
To demonstrate in the field the ability of purposefully planted eastern cottonwood trees to help remediate shallow trichloroethylene (TCE) contaminated ground water.



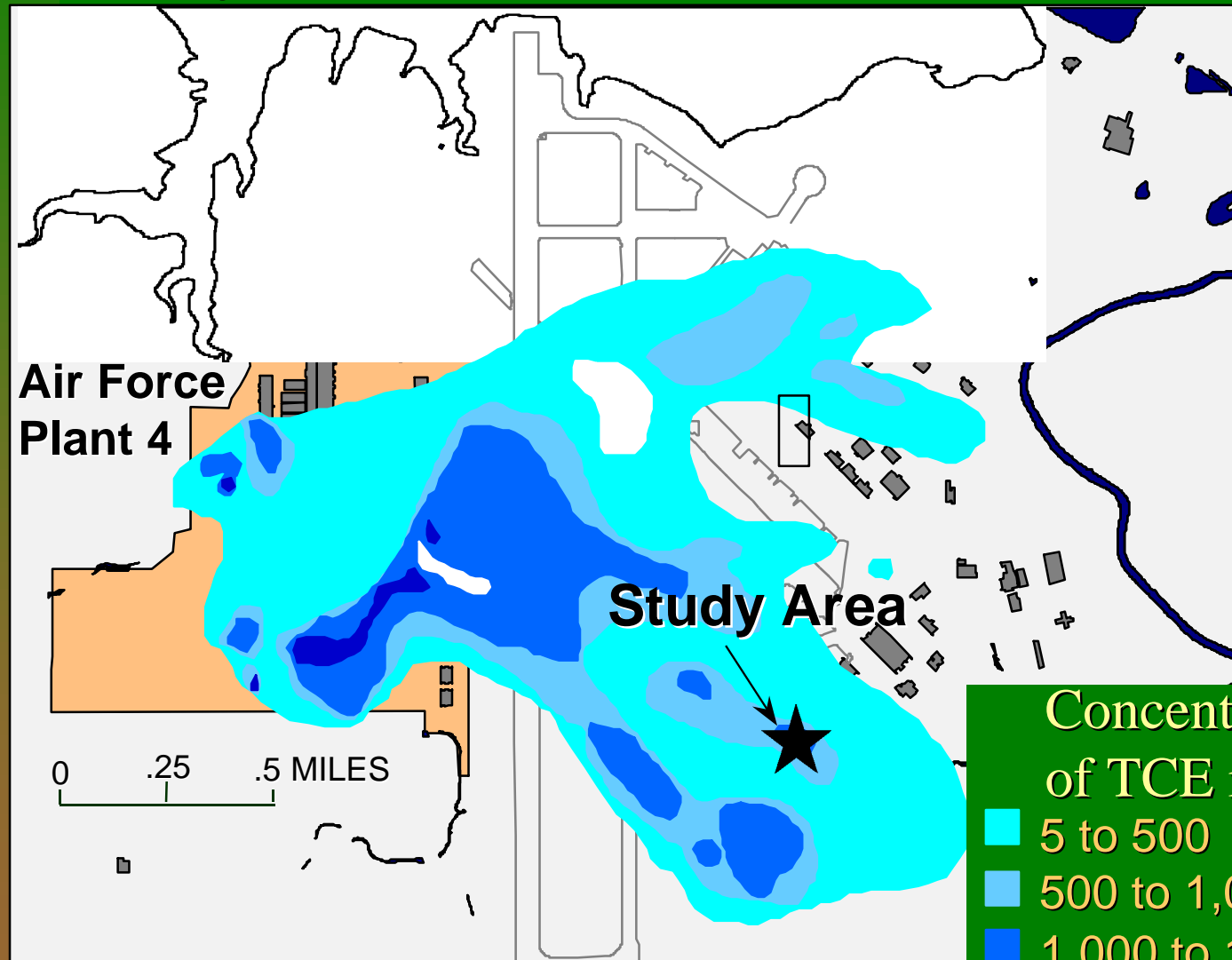
Acknowledgments

- Environmental Security Technology Certification Program of the Department of Defense
- Superfund Innovative Technology Evaluation Program of the U.S. Environmental Protection Agency
- Aeronautical Systems Center/Environmental Management Directorate at Wright Patterson AFB

Conceptual Model / Treatment System



Study Area - Fort Worth, TX



Concentration
of TCE in ug/L

- 5 to 500
- 500 to 1,000
- 1,000 to 10,000
- >10,000 <100,000



Site Hydrology

- Aquifer — Silty Sand, 2 - 5 feet thick, Aerobic
- Water Table — 8 - 14 feet bls
- Recharge from Precipitation — 2.5 in/yr



Scope and Approach

- What Affect Do The Trees Have On The Dissolved TCE Plume?
 - Monitor / model changes in ground-water levels
 - Monitor ground-water geochemistry
 - Compute changes in the mass flux of TCE across the downgradient end of the site



Scope and Approach

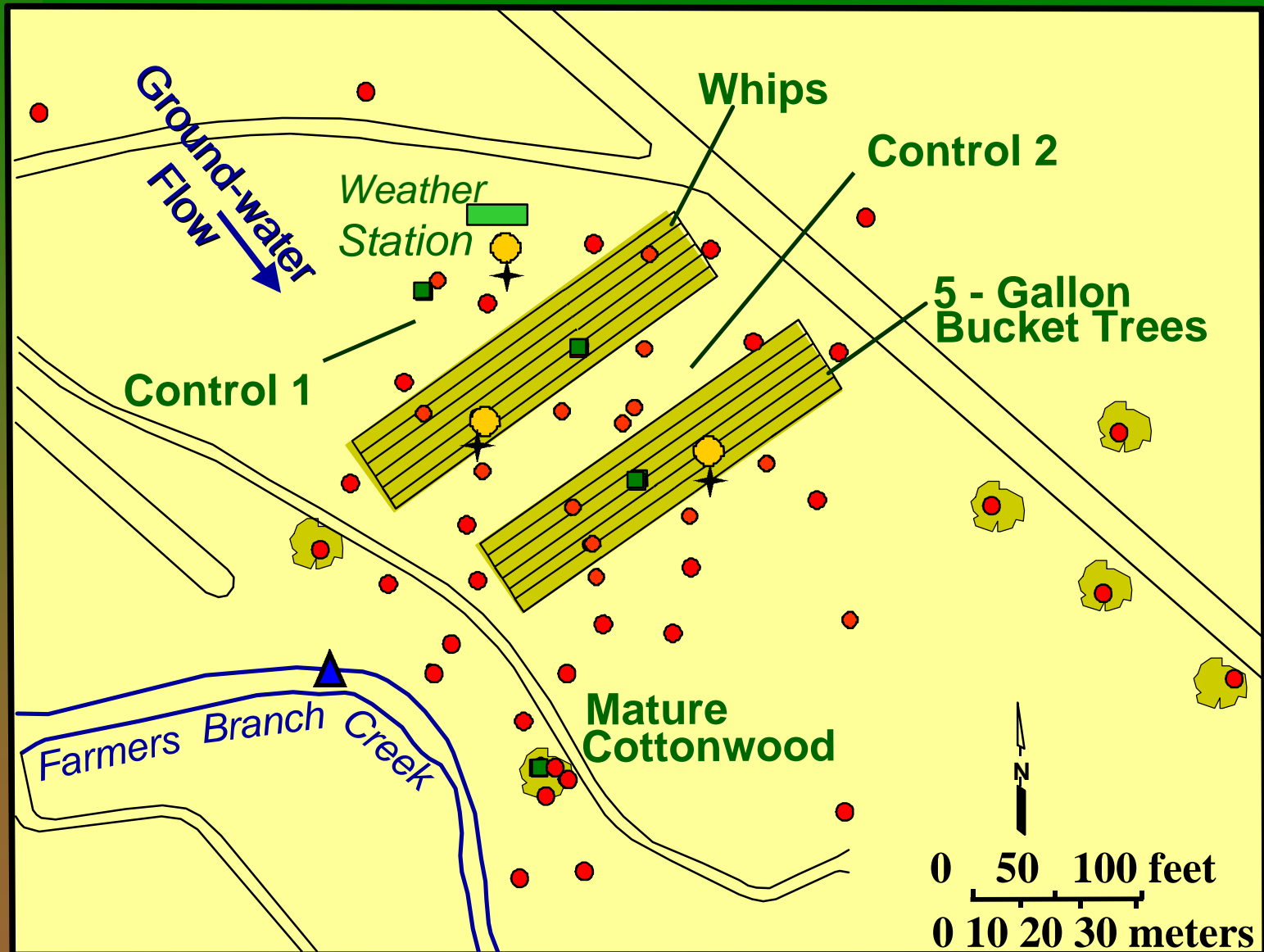
- What Is The Fate Of TCE At The Site?
 - Compute tree transpiration rates
 - Investigate enzymatic activity of the trees
 - Investigate microbial activity in the soils
 - Compare concentrations of daughter and parent compounds in the ground water, soil, and tree tissues



Scope and Approach

- How Practical Is The Technology?
 - Document how long it takes for the trees to affect the plume
 - Compare root development between trees of different ages
 - Document how much it costs

Experimental Design







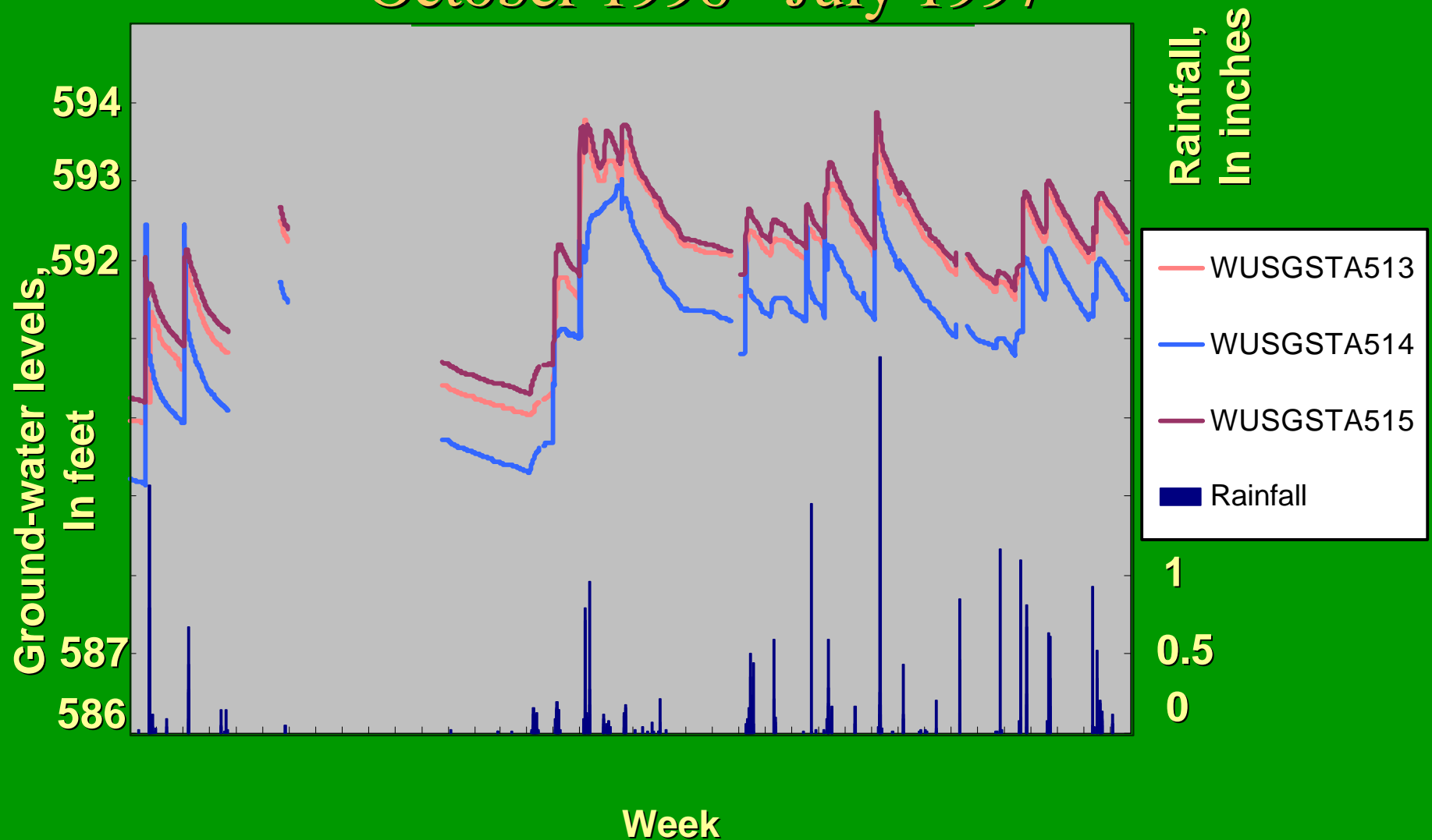
Root Growth

- Roots in both tree stands reached the water table within the first two growing seasons
- Five-gallon bucket trees had overall greater mass and deeper roots than the whips after 17 months
- Notable amount of roots have entered the well screens



(Hendrick, Univ. of Georgia, written commun., 1997)

Ground-water levels and Rainfall October 1996 - July 1997



Transpiration (Summer 1997)

- WHIPS
6.2 kg/day (mean)
- 5-GALLON BUCKET TREES
12 kg/day (mean)
- MATURE COTTONWOOD TREE
1140 -1320 Kg/Day
(300-350 gallons per day)



(J.M. Vose, U.S. Forest Service,
written commun., 1997)



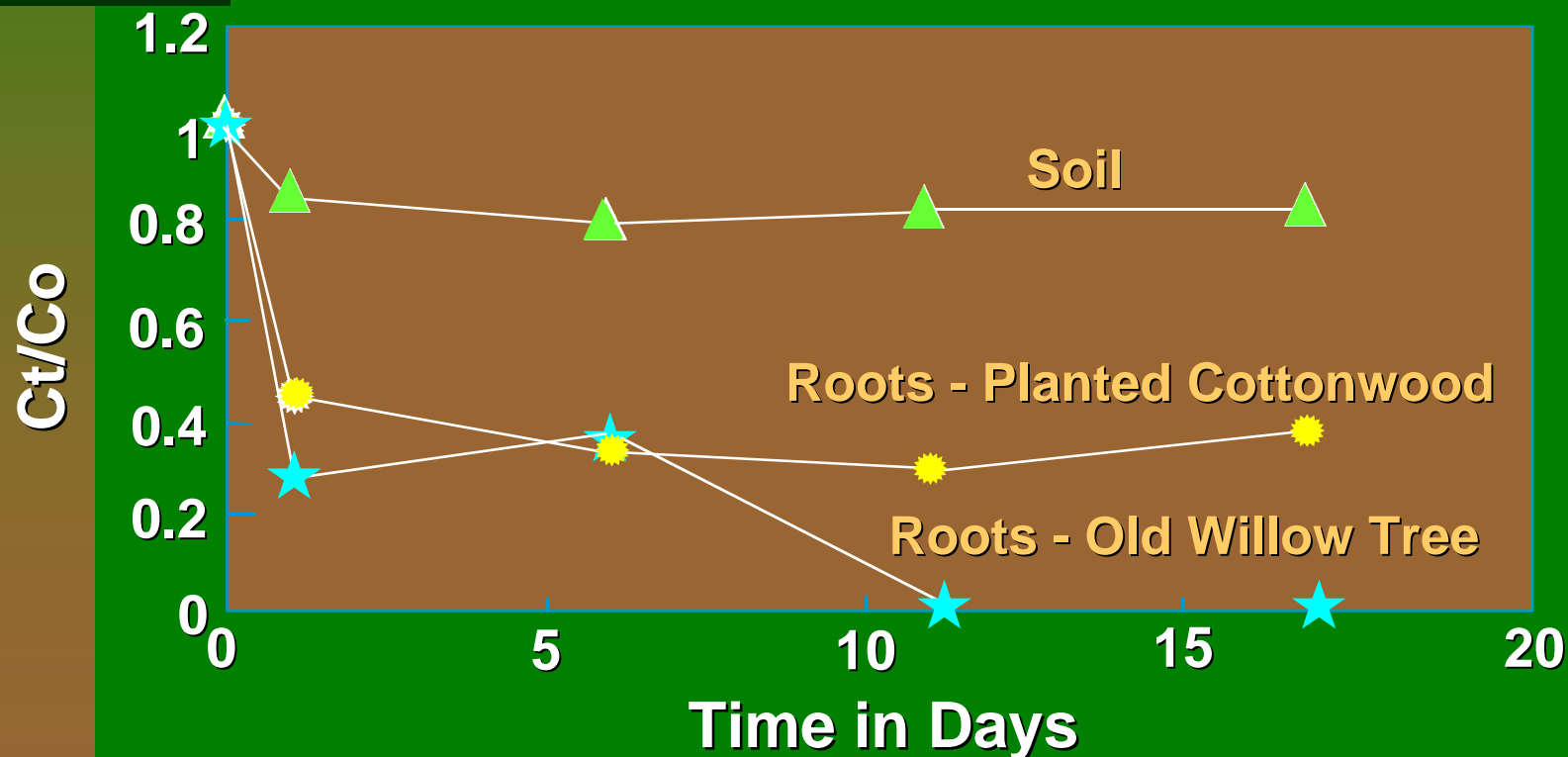
Hydraulic Control (Modeling Approach)

- Determine required amount of pumpage
(Ground-water flow model - MODFLOW / MODMAN)
- Predict future transpiration at demonstration site
(Hydrologic model - PROSPER)
- Determine timing of hydraulic control by planted trees
(Combined results of MODFLOW and PROSPER)
- Compute mass flux changes attributable to trees
(Transport model - MOC3D)



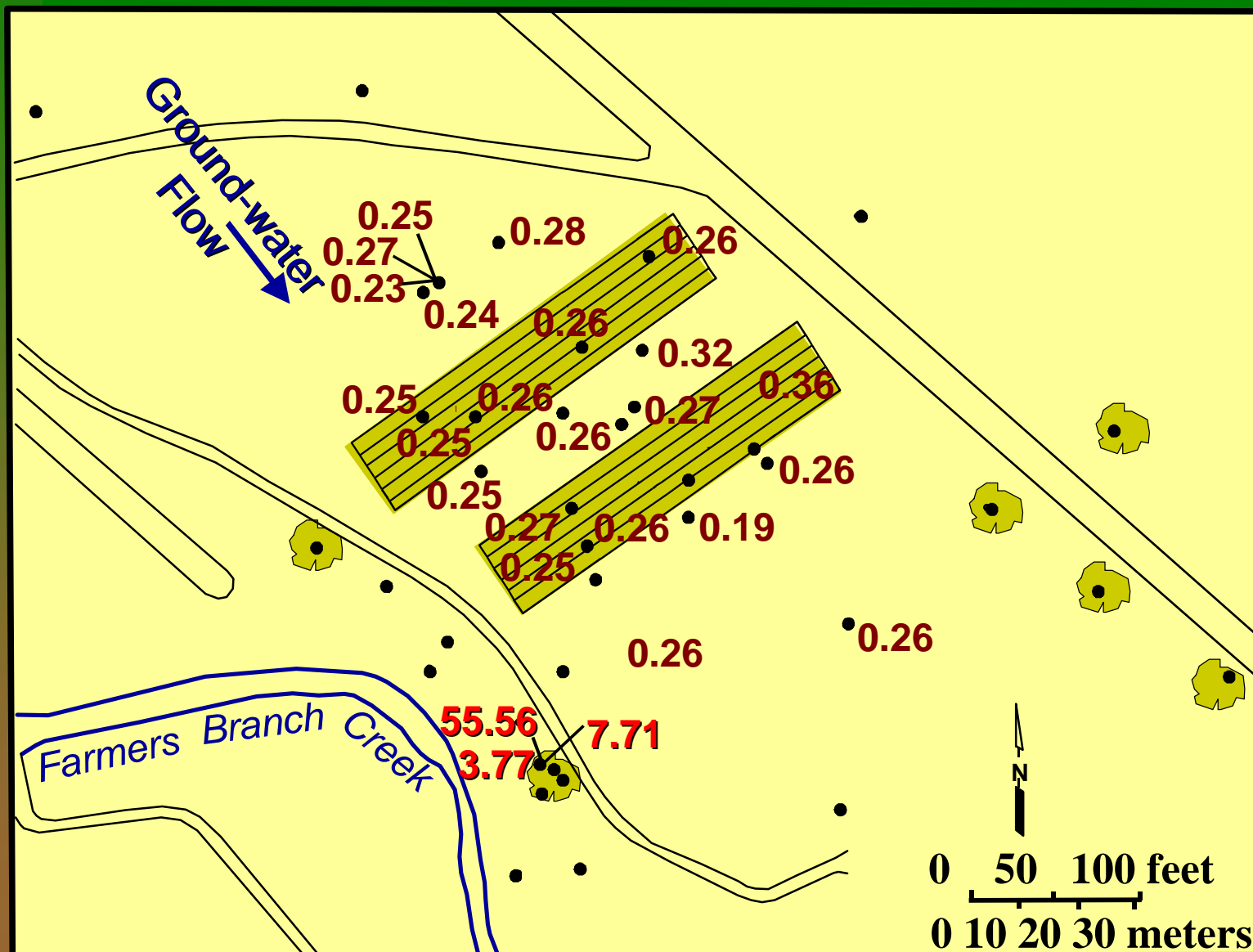
Uptake Rate and Possible Transformation of PCE by Soils and Roots from the Site

(Preliminary)

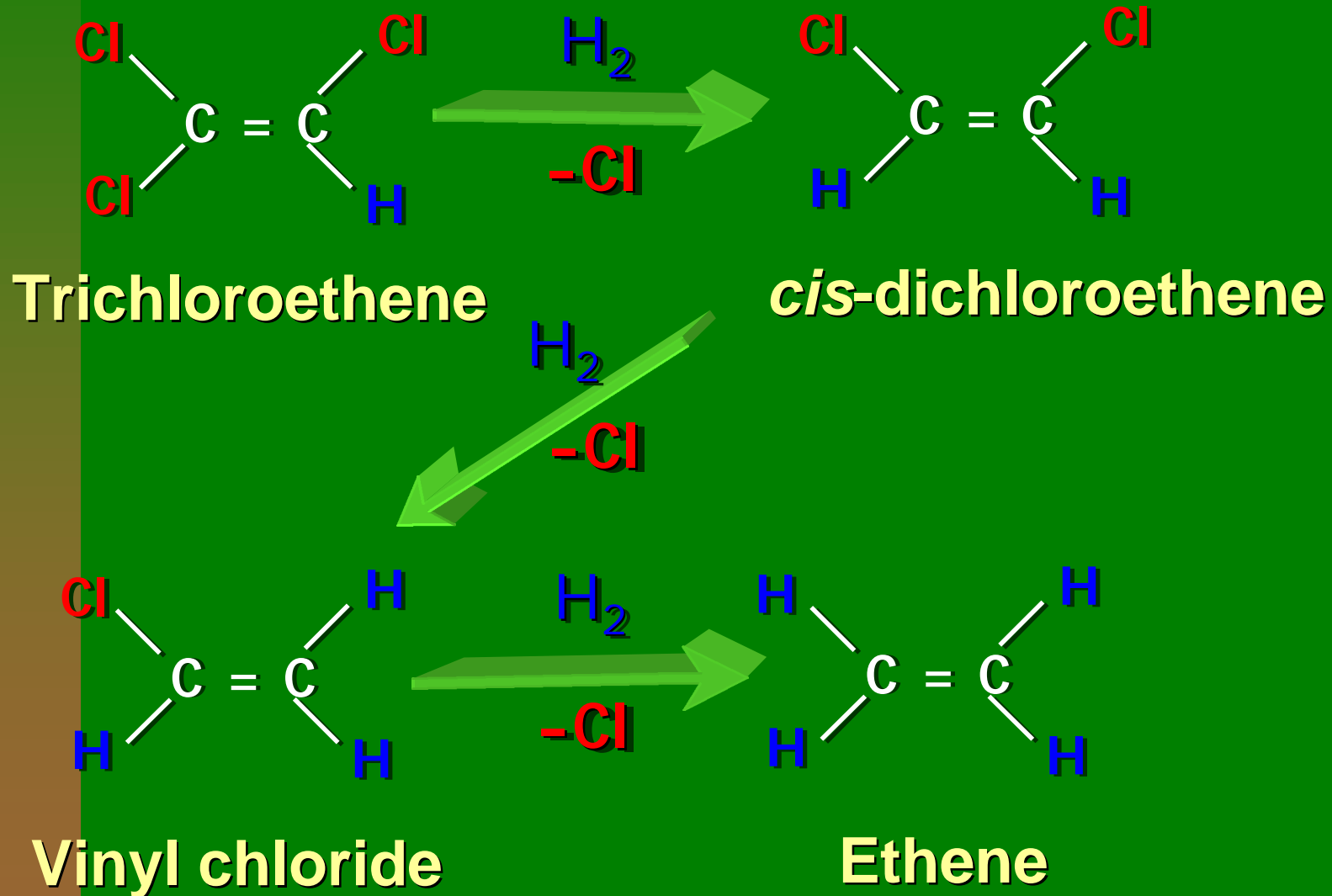


(Nzengung, Wolfe, and McCutcheon, USEPA, written commun., 1997)

DCE / TCE in Ground Water, July 1997



Reductive Dechlorination of TCE





Ground-Water Chemistry Near Mature Tree(s)

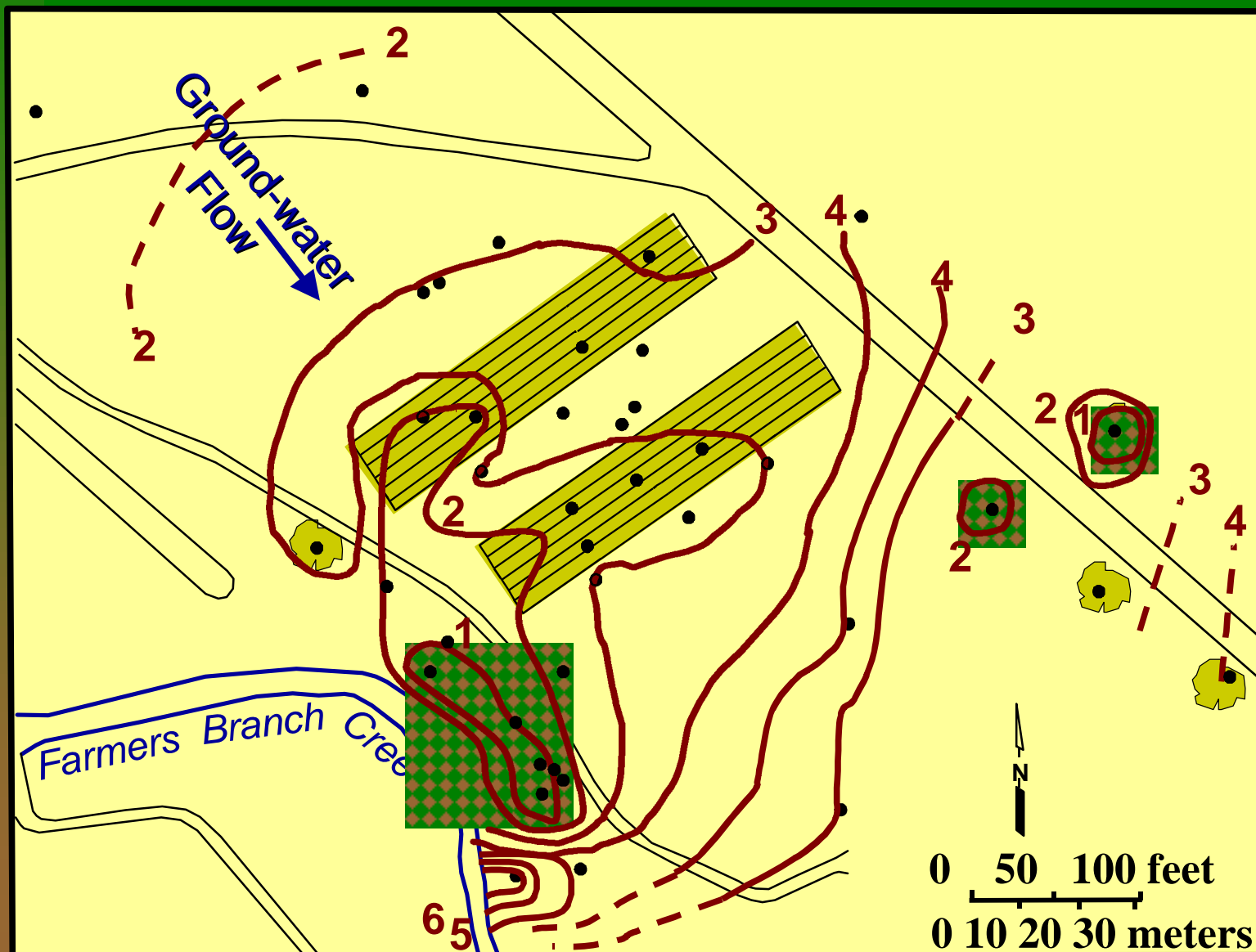
- **Mature Cottonwood vs. Planted Trees**

- Higher Dissolved Organic Carbon
- Lower Dissolved Oxygen
- Higher Total Iron
- Higher Molecular Hydrogen
- 25 % Greater Bicarbonate and $p\text{CO}_2$
- 80% Lower TCE
- 100 % Greater cis-1,2 DCE

- **Other Mature Trees**

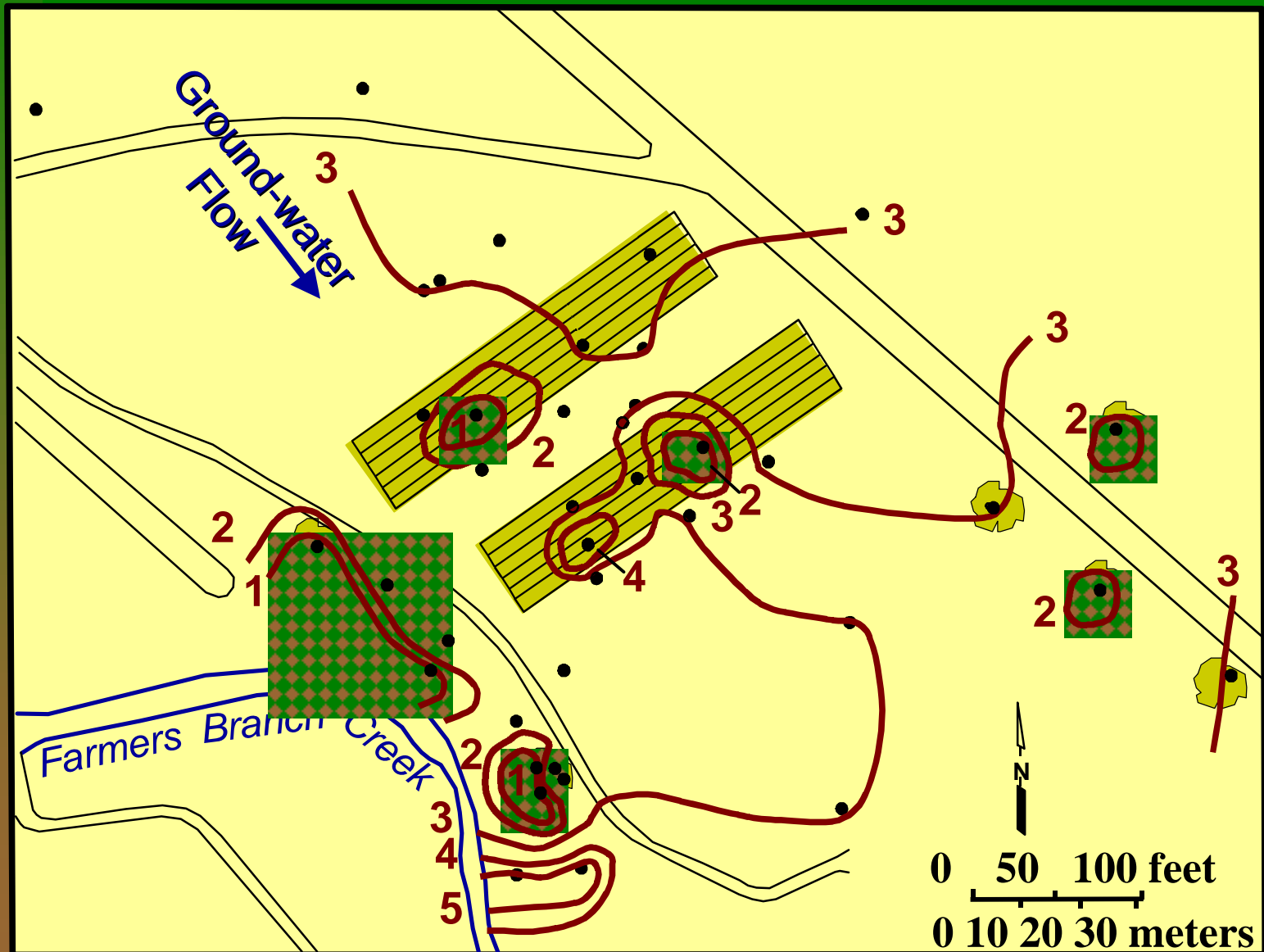
Altered Redox Conditions and Changes in the
cis-1,2 DCE and TCE Signatures

Distribution of Dissolved Oxygen (mg/L), November 1997



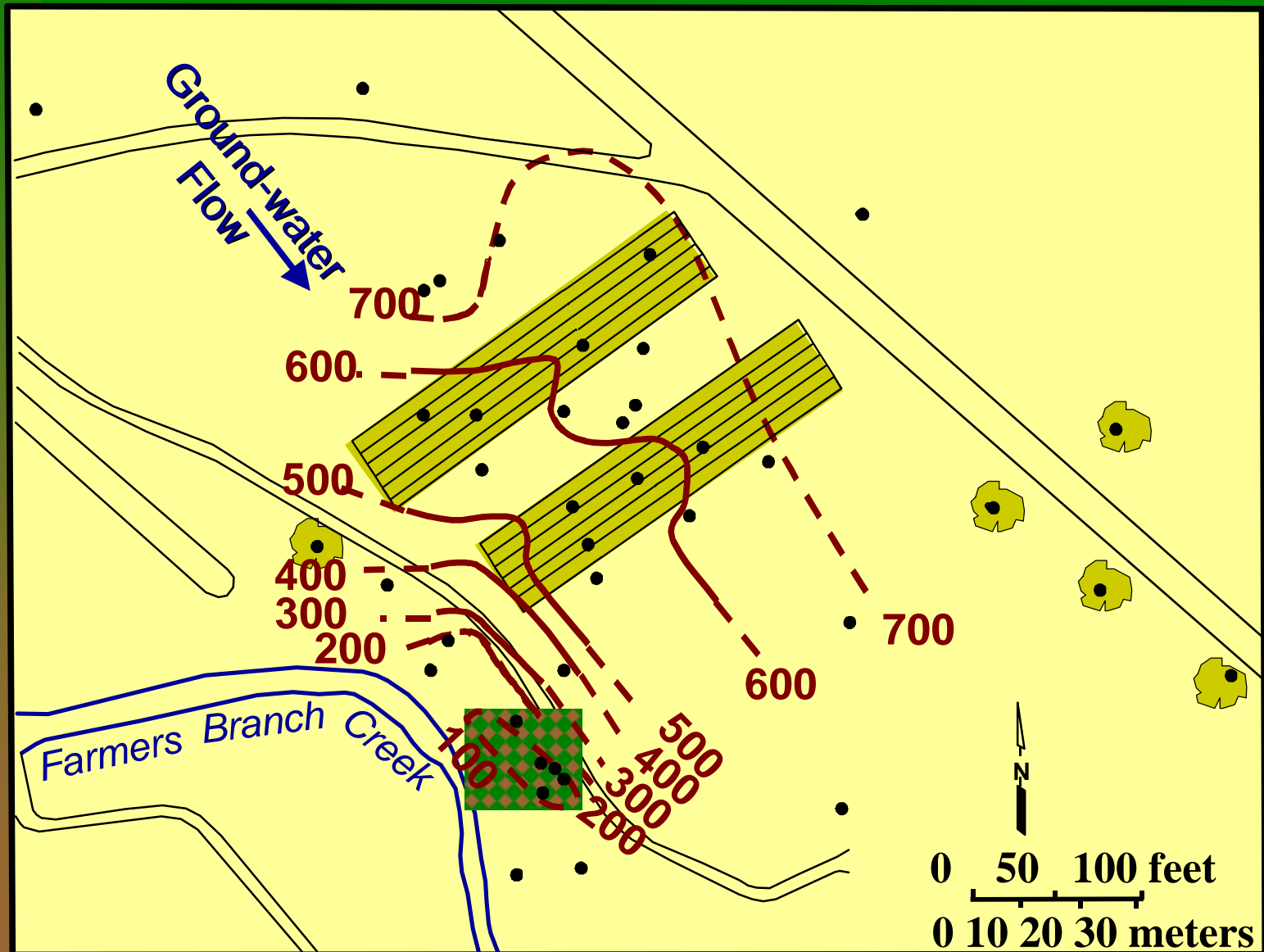
(Modified from R.W. Lee, USGS, written commun., 1998)

Distribution of Dissolved Oxygen (mg/L), February 1998



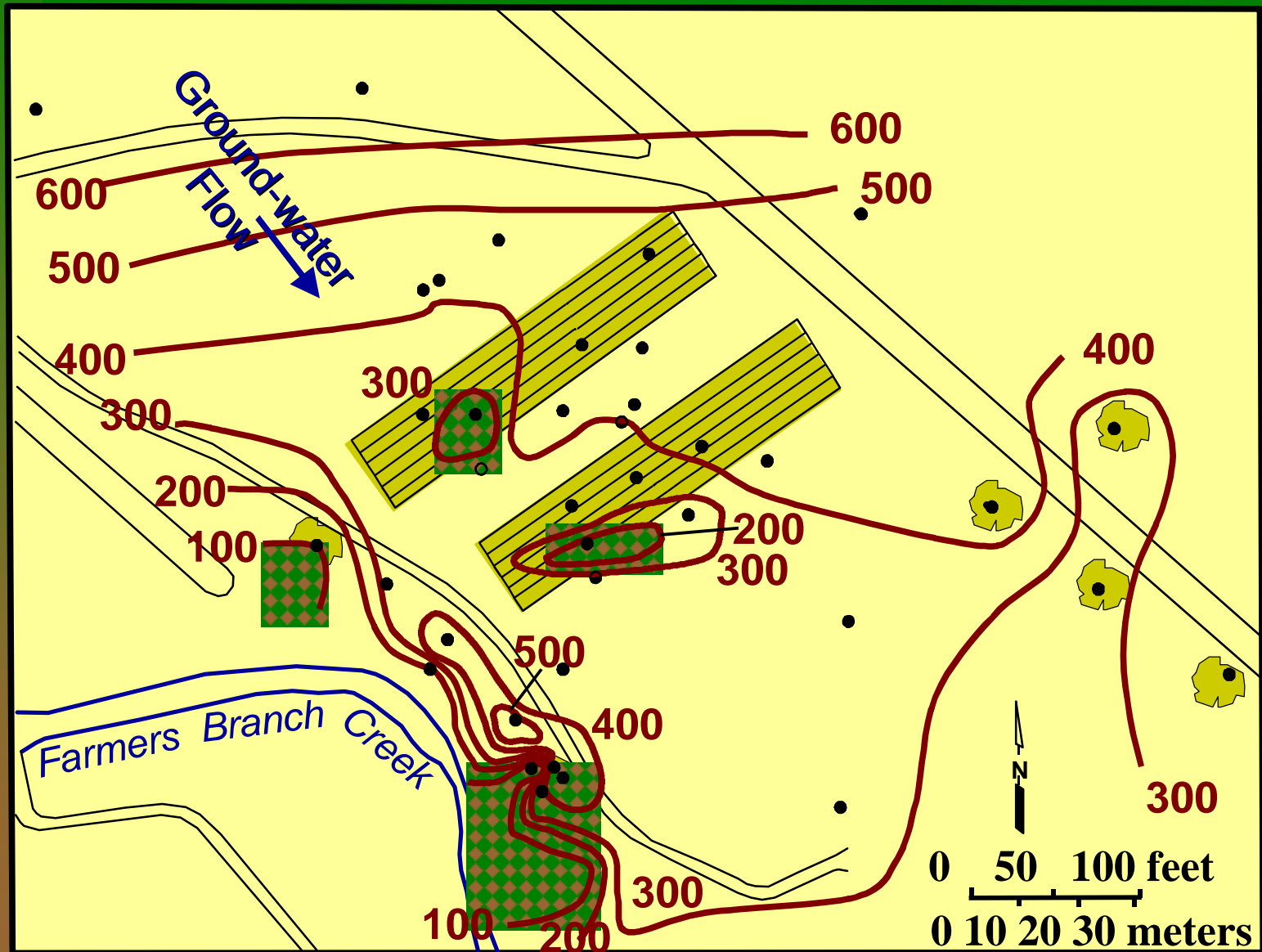
(R.W. Lee, USGS, written commun., 1998)

Distribution of TCE ($\mu\text{g/L}$) in Ground Water, November 1997



(R.W. Lee, USGS, written commun., 1998)

Distribution of TCE ($\mu\text{g/L}$) in Ground Water, February 1998



(R.W. Lee, USGS, written commun., 1998)



Partially Validated Process

Root growth results in changed redox conditions in the underlying aquifer, which promotes microbially mediated degradation of dissolved TCE

- Trees introduce labile organic matter into the aquifer
- Dissolved oxygen is subsequently consumed, creating iron reducing conditions
- Reducing conditions lead to reductive dechlorination of TCE in the aquifer



Cost and Performance To Date

- Cost (One acre demonstration site):
 - Treatment system \$63K
- Performance to Date:
 - Roots at water table within 17 months
 - 19-year old tree pumps ~350 gal/day
 - Timing of hydraulic control and changes in mass flux yet to be determined
 - PCE transformed in presence of roots from site
 - Reductive dechlorination occurs in aquifer beneath existing mature trees